ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

The Causes and Remedial Measures of Cracks on Building Foundation on Expansive Soil Area Found at Koye-Feche Projects

A Project Submitted to the School of Graduate Studies of Addis Ababa Science & Technology University In Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Geo-Technical Engineering.

By:

Shewa Habte Shume

June, 2017

Addis Ababa, Ethiopia

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College: College of Architecture and Civil Engineering

Department: Civil Engineering

Program: Geotechnical Engineering

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DECLARATION

The project is my original work, has not been presented for a degree in any other university and that all sources of material used for the project have been duly acknowledged

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Date of Submission: June 09, 2007

APPROVAL

This **Meng Project** entitled with **"The Causes And Remedial Measures Of Cracks On Building Foundation On Expansive Soil Area Found At Koye-Feche Projects"** has been approved by the following examiners in partial fulfillment of the requirement for the degree of master of Engineering in **Construction Technology and Management**.

Date of Defense: May 27, 2017

Members of the Examining Board:

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LIST OF ACRONYMS AND ABBREVIATIONS

CIS	Corrugated Iron Sheet
HCB	Hollow Concrete Block
ACI	American Concrete Institute
TP	Test Pit
LL	Liquid Limit
PL	Plastic Limit
PI	Plastic Index
LI	Liquidity Index
ρd	Dry Density
ω	Water Content
SP	Swelling Pressure
NG	Normal Ground Level

ABSTRUCT

Cracks are one kind of universal problem of concrete construction, it affects the building artistic and the function, and it also destroys the wall's integrity, affects the structure safety, even reduce the durability of structure. The problem of cracking in building is becoming a difficult puzzle for engineers nowadays. Cracking is an unavoidable response of any structure while designers are trying to eliminate many of the causes of cracking and design tolerance for other factors. We all want our building structurally safe but it is not so easy. Some faulty steps during construction and some unavoidable reasons different type of cracks starts to appear on various structural and non- structural parts of the building. So, timely identification of such cracks and adopting preventive measure are essential. The repair materials and repair technique are different depending upon forms of cracks according to their positions in structure. Some types of cracks seriously need attention as they are structurally hazardous. Masonry cracks are objectionable because they are the primary source of water permeance and may be aesthetically displeasing or indicative of structural distress. Cracks are the most frequent cause of masonry's failure to perform as intended. The types, locations, patterns, sizes, and causes of cracks are discussed in this project. Building cracks are most common type of problem in any type of building. So, it is important to understand the cause and the measures to be taken for prevention.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Most residential construction today is supported on either concrete slabs-on-grade or on concrete or masonry foundations. There are a number of different foundation types, each of which must provide both the strength and stability to support the weight of the structure. concrete, masonry, mortar and likes have low in shear strength and tensile strength. Due to this problem different cracks visible on many buildings in the world. Cracks on concrete have many causes. They may affect appearance only, or they may indicate significant structural distress or a lack of durability. The proper repair of cracks depends on knowing the causes and selecting the repair procedures that take these causes into account; otherwise, the repair may only be temporary. Successful long-term repair procedures must attack the causes of the cracks as well as the cracks themselves.

Koye-feche condominium project has found at southern part of Addis Ababa next to Addis Ababa Science and Technology University at Akaki-Kality sub city with a latitude of 8º54'47'' North and a longitude of 38º47'21'' East and has 2125m above sea level.. Koye-Feche condominium project is the largest project in Ethiopia in the history of condominium projects. There is about 50000 condminium houses have been built on there under 20/80 housing program. It has cover an area of 732 hectares and costs a total of more than 6.5 billion birr for the construction of the house. This has expected to job opportunity for 45000 unemployed compatriots. The houses will benefit more than 200000 households when completed.

At Koye-feche condominium projects in the summer season I have seen that much cracks on many of the buildings at foundation parts. Some of which are seriously damaged. The project has all the three parties professionals for each blocks. But they can not to stop the cracks or other failures on the project. Even some of them are tried to repair on time but still the building cracks not controlled, it cracks again. So due to this I have interested to study on the causes and its remedial measures of the project failures.

Nowadays masonry is still used in important structural and non-structural elements. In many situations, as is usual in northern European countries, masonry is commonly the structure in load-bearing masonry buildings. In other applications, such as in southern European countries, masonry is mainly used for infill walls in buildings with reinforced concrete frames. Theoretically the infilling walls have no relevant mechanical behavior, but in practice these walls have structural importance since some transference of loading can occur due to building structure/wall interactions. These interactions, as well as other effects like dimensional changes of the walls, due to thermal or moisture movements or foundation settlement, can lead to several different defects in masonry walls in serviceability states, such as cracking, one of the most important [1].

Occurrence of various crack patterns in the building during construction or after completion when it is subjected to super imposed load or during the service life, is a common phenomenon. A building component develops cracks whenever the stress in the components exceeds its strength. Stress in the building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, foundation settlement etc. or it could be induced internally due to thermal movements, moisture changes, elastic deformation, chemical action etc. *[2]*.

The commonly used building material namely masonry, concrete, mortar etc. are weak in tension and shear. Therefore the stresses of even small magnitude causing tension and shear stresses can lead to cracking. Internal stresses are induced in the building components on account of thermal movements, moisture change, elastic deformation, chemical reactions etc. All these phenomenon causes dimensional changes in the building components, and whenever this movement is restraint due to interconnectivity of various member, resistance between the different layers of the components etc., stresses are induced and whenever these stresses (tensile or shear) exceed the strength of material cracking occurs.

Depending upon the cause and certain physical properties of building material these cracks may be wide but further apart or may be thin but more closely space. As a general rule, thin cracks even though closely spaced and greater in number, are less damaging to the structures and are not so objectionable from aesthetic and other considerations as fewer number of wider cracks.

1.2. Problem of the Statement

The area soil is highly expandable characteristics which has a high potential to swelling and shrinkage characteristics of the soil. Besides of its expansiveness; The excavated area around the building is not filled with select material; The method of working fill material to the foundation is not properly done with proper compaction method; During the summer season majority of the projects (koye feche condominium projects) were submerged with flood. the stone masonry around the building were exposed to different types and size of cracks. and also there is a settlement of the back fill material under grade beam.

1.3. Objective of the study

1.3.1. General Objectives

- Expansive soil has a potential to swell and shrink with a change in moisture content of the soil. This swelling and shrinkage characteristics of the soil produce crack on the building. to produce constant moisture content of the foundation soil keeps the soil from swelling and shrinkage characteristics.
- To identify the cause of cracks and type of cracks on the project.

1.3.2. Specific Objectives

- To minimize cracks in the building and to give remedial measures for maintaining cracks
  on the project.

1.4. Methodology

The research addresses the general objectives and tries to investigate the cause of building failure based on the existing theories and principles. Uses secondary data of soil test result to the project for determining the soil characteristics of the study area. Site Observation and making an interview are used as a method for this paper work. Micro soft excel is used for making the graph. The study includes assessment of forty four randomly selected buildings found on koye-feche condominium projects. Simple random sampling method is adopted.

1.5. Limitation

The project is being newly constructed project it is difficult to see that all the problems on different parts of the building specially in the finishes. rather I have shown on small buildings, to the site inspector office and the area dwellers of residence.

1.6. Project Organization

The project consists of five chapters. The first chapter is the introduction part and it consists of the back ground, statement of the problem, the objective, the scope of the project, limitations and organization of the project. The second chapter is literature review on general review, classification, types and arrangements of cracks, factors affecting volume change, causes of defects and method of measurement. The third chapter comprises method of sampling and previous test result to the area, the fourth chapter is data observation and damage analysis the fifth chapter is discussion and results on the observed buildings and The sixth chapter consists of conclusion and recommendation.

CHAPTER TWO

2. LITRATURE REVIEW

2.1. General

Concrete structure has been started applying since the mid-19^{th} century, because of the low quality of cement and concrete in that time, so the development was slow. Until the end of the 19th century, concrete structure was getting faster development with the development of production, experimental work, computational theory and improvement of construction techniques, material. It became one of the most widely used building materials in the modern construction. Cement, aggregate and water mixture can be the normal raw material. In general, drinking water can fulfill the requirements of the concrete mixing water, excess amount of acid, alkali and salt can bring harmful effects to concrete. Raw material also affect to capacity, weight, strength and other properties of concrete [3].

Some researchers already worked on related topics of causes and remedies of cracks such as Study type of cracks in construction and its controlling done by [Kazem Reza Kashyzadeh and Neda Aghili Kesheh 2012], it shortly describes about what every civil engineer should know about face of the building i.e. cracking. Causes and evaluation of cracks done in concrete structure by [Sayed Mohd Mehndi et al. 2014], they explained about the evaluation of cracks that can be done by different technique like Crack Compactor and by ultrasonic Testing. Building cracks-causes and remedies by [Grishma Thagunna 2014], from this research it is found that building cracks has direct and indirect impacts and building cracks do not cause structural problem in direct way but it facilitates the activities which ultimately cause the problem. Prevention & repair of cracks in concrete structures by [B.B.Gamit et al. 2014], they broadly classified about the structural and non structural cracks that occurs in building along with their causes and remedy. Study on control of cracks in a structure through Visual Identification & Inspection [Kishor Kunal and Namesh Killemsetty 2014], they talk about how visual inspection of cracks can be helpful in order to identify and categorize them with respect to various parameters by taking case study of an institutional building [8].

the general quality improvement expected from the profusion of codes and standards, in recent years some building masonry cracking defects are still being reported with high frequency in different countries. These defects incur costs and can involve litigation between different parties involved in the construction process. In fact, although building construction is an industrial activity, we know that buildings are still prototypes and in some areas, like masonry, the relationship between traditional technologies and local materials is relevant and important, so different practices evolve in different areas. Therefore, these aspects justify that more attention should be paid to design in order to avoid or minimize defects associated to the serviceability behavior on masonry walls, whether structural or non-structural [1].

2.2. Classification of Cracks

Occurrence of various crack patterns in the building during construction, after completion when it is subjected to super imposed load or during the service life, is a common phenomenon. A building component develops cracks whenever the stress in the components exceeds its strength. Stress in the building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, foundation settlement etc. or it could be induced internally due to thermal movements, moisture changes, elastic deformation, chemical action etc.[2].

Cracks in buildings could be broadly classified as structural and non-structural cracks.

Structural Cracks: These occur due to incorrect design, faulty construction or overloading and these may endanger the safety of a building.

- Cracking due to the settlement of foundations, excessive loading and deformations (shear and flexural) and other effects (creep, shrinkage and thermal);
- Local crushing due to high compressive loads;
- Corrosion of metallic elements or chemical reactions [1].

Nonstructural Cracks: These are mostly due to internally induced stresses in buildings materials and do not endanger safety of a building but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations due to penetration of moisture through them nonstructural cracks may spoil the internal finishes thus adding to the cost of maintenance, or corrode the reinforcement, thereby adversely affecting the stability of the Structure in long run. e.g. Vertical crack in a long compound wall due to shrinkage or thermal movement[2].

The most common masonry non-structural defects are:

- Undesired changes in the physical properties of the materials due to the presence of water/humidity (from the soil, construction works, precipitation, condensation, hygroscopicity, accidental causes, …) thus affecting the durability, aesthetics and the environmental conditions of the buildings or building elements;
- cracking in non-structural elements (e.g. partition walls and applied rendering systems) due to the interaction with structural elements, thus making this defect associated with the structural ones;
- ageing and degradation of the materials, in particular rendering systems, due to continuous exposure in the environment, inadequate use or absence of maintenance procedures;
- Inadequate behavior in other aspects (non-structural safety, environment comfort conditions, energy consumption) [1].

- Cracks may appreciably vary in width from very thin hair crack barely visible to naked eye to gaping crack. Depending upon the crack width cracks are classified as : Thin Crack - less than 1 mm in width, Medium Crack - 1 to 2 mm in width, Wide Crack - more than 2 mm in width. Crazing - Occurrence of closely spaced fine cracks at the surface of a material is called crazing.

Cracks may of uniform width throughout or may be narrow at one end gradually widening at the other. Crack may be straight, toothed, stepped, map pattern or of random type and may be vertical, horizontal or diagonal. Cracks may be only at surface or may extend to more than one layer of material. Cracks due to different causes have varying characteristics and by the careful observations of these characteristics, one can diagnose the cause of cracking for adopting the appropriate remedial measures[2].

2.3. Types and arrangements of Cracks

2.3.1. A Step Cracks

Step cracks, stair step cracks or stepping cracks all refer to cracks that follow the mortar joints in a block wall. The cracks step up or down along the mortar. In many cases, this type of crack is caused by minor movement of the footing, shrinkage or wall movement, and by itself is not a major cause for concern; however, wide cracks or step cracks combined with other cracks and movement indicate a problem. A combination of cracks needs a professional review[12]

2.3.2. Vertical Cracks

Vertical (up and down) cracks can be caused by simple shrinkage of materials. These cracks often occur in the control joints of poured walls. They appear as hairline cracks in mortar joints and through blocks in a cement block wall. Some vertical shrinkage cracks in poured concrete can be up to 1/8 inch wide. Cracks in block walls should be very narrow, without horizontal movement. Vertical cracks are an issue if they are wide, tapered from top to bottom, or found in combination with other cracks. They can occur because of settlement, wall movement or tipping walls. Vertical cracks also occur if a wall is pushed in and breaks away from the adjacent corner or surface. Vertical cracks with horizontal or shear movement at the crack always indicate a problem. Vertical shear cracks at a corner with no horizontal cracks indicate a large amount of water freezing at the corner. In this case, the center of the wall can be stable[12].

2.3.3. Horizontal Cracks

Horizontal (left to right) cracks can appear at the mortar joints in block walls. They indicate that the wall is displaced horizontally. As the wall is pushed in, the joint opens up inside the basement, and a similar crack will occur outside near the base of the wall. Horizontal cracks are caused by wet soils, poor maintenance of surface water and frost. Horizontal cracks in block walls always need to be taken seriously. A horizontal crack combined with step or vertical cracks indicates a problem. When the crack is over 1/8 inch wide and there is horizontal wall movement of 1/2 inch or more, the problem needs to be addressed. Horizontal cracks often will change seasonally. When there is water in the soil, the soil may expand a common trait of clay soils. When the wet soil expands, the wall may be pushed in and the horizontal crack may open further. When the soil dries, the crack may close. Frost in exterior soil causes similar movement and cracking as the frost expands the soil. If soil settles behind a wall when the wall is bowed seasonally, it will remain displaced. A horizontal crack can happen suddenly under adverse conditions. Rain and snow melt combined with freezing temperatures can cause a wall to move[12].

2.3.4. Measure Displacement

The displacement or movement of the wall is a critical measurement to determine whether a wall is in jeopardy. Measurements can be made with a 4-foot or longer level, a laser level or a plumb bob. The key is to measure over the height of the wall and then compare measurement to the corners. In many cases, corners don't move because the block is "woven" together in a strong joint that resists horizontal movement. The corner of a concrete wall also is very strong. If the wall is displaced in relation to the corner, there may be a problem. If the corner is tipped and the whole wall is similarly tipped, the wall might have been built out of plumb. As the block wall was built, a string was pulled from the corner to align the block of the wall; if the corner is tipped, the wall will be tipped. The plumb bob measurement makes the movement easy to visualize. The weight at the bottom of a string holds the string "plumb" or vertical, and you can measure from the vertical string back to the wall. If you find cracks and displacement over 1/2 inch, you should start to question the stability of the wall and consider possible repairs. Wall displacement also may be referred to as deflection. However, technically "deflection" usually describes materials that move under load or stress and then move back to their original position once the load is removed [12].

2.3.5. Multiple Horizontal Cracks.

At times, you may see multiple horizontal cracks that occur in several mortar joints above and below each other. This often is the sign of ongoing movement or movement on several occasions

2.3.6. Combination of Cracks.

All combinations of cracks are cause for concern. As the wall is pushed in the horizontal cracks open. With more movement, the wall breaks away from the corners, resulting in step cracks and vertical cracks. The corners are stable, while the wall breaks away. This type of movement and cracking typically occurs in a block basement, not in one made of poured concrete When bowing or movement occurs in a poured concrete wall there will be a combination of vertical and 45-degree angle cracks. The cracks allow the wall to break away from the stable corners and move inward. As the wall moves inward, the wall splits away from the adjacent surface with a vertical shear crack and a step crack. On the outside, vertical cracks will occur in joint near the corners[12].

2.3.7. Displaced Walls Tipped, Shear and Slide

Walls also can move with little signs of cracking. A wall that tips in over time will be found by measuring for displacement and movement relative to the floor framing. This can happen in block and cement walls. Severe movement creates vertical or step cracks that allow a section of wall to break away. With minor movement, the problem can occur without creating cracks and it is hard to detect. The framing sill plate could be split or could slide on the top on the top of the wall. Walls also can be pushed in at the base when there is slip or shear at a lower mortar joint. In this case, soil pressure forces the wall in and a lower block joint is broken or sheared. This often is hard to see with a cursory look, but it is a serious issue because the wall has lost its ability to resist horizontal pressure, which is greatest at the base of the wall. The poured concrete floor is holding the lower block in place [4].

2.3.8. Exterior Signs of Problems Brick Veneer Movement

A basement supports the brick or stone veneer on homes that we call brick or stone homes (although they actually are wood-framed homes with masonry veneer). If a basement wall has serious cracks and inward displacement, the top of the wall tips outward. As the top tips out, the brick veneer supported by the wall also tips outward. You also may see horizontal cracks in the veneer, or the veneer may be pulling away from the wood framing. You will see this movement at the end joint between the veneer and the siding. Look for additional trim or caulk filling a gap at the top of the masonry veneer [2].

2.3.9. Displacement at Siding And Beam-End Cracks

Often, when a basement is pushed in, the top of the wall undergoes significant movement. You may see this movement outside the home. There will be vertical cracks at the corners where the wall breaks away from the corners. The block covering the end of the beam may be pushed out as the wall moves in because the beam normally will not move. You also can detect serious movement by measuring from the siding to the top of the block wall.

2.3.10. Tipped Stoops

Tipped entrance stoops can cause a basement problem and often result from the lack of a proper footing for support. If the stoop tips down, away from the home, the pressure of movement can displace and crack a block wall. If the stoop support is not properly designed and executed for the poured wall, the concrete foundation wall can crack. A stoop that tips toward the foundation wall can also crack a block wall. When a stoop tips in, it will direct water toward the foundation wall and this always is a problem [12].

2.3.11. Floor Cracks

Basement floor cracks are common, because concrete shrinks as it cures. Don’t be concerned with random spider web-like cracks or cracks that occur from an inside corner. These often are shrinkage-related. Basement floors often have gaps between the floor and the wall or around the sump pump crack in a corner. Do be concerned if the cracks are parallel to the wall and footings or if there is vertical movement associated with the cracks. Displacement at the cracks, or floor cracks that align with wall cracks, can indicate a problem. Floors that are tipped and cracked need to be evaluated. Floors that are heaved and cracked are a problem. Heaving indicates hydrostatic pressure from a hampered drain tile system or an inoperative or improperly adjusted sump pump [8].

2.4. Factor Affecting Volume Change

The common cause of cracking in concrete is shrinkage due to drying. This type of shrinkage is caused by the loss of moisture from the cement paste constituent, which can shrink by as much as 1% per unit length. These moisture-induced volume changes are a characteristic of concrete. If the shrinkage of concrete could take place without any restraint, the concrete would not crack. It is the combination of shrinkage and restraint, which is usually provided by another part of the structure or by the subgrade that causes tensile stresses to develop. When the tensile stresses of concrete are exceeded, it will crack. Cracks may propagate at much lower stresses than are required to cause crack initiation.

Most of the building materials with pores in their structure in the form of intermolecular space expand on absorbing moisture and shrink on drying. These movements are cyclic in nature and are caused by increase or decrease in inter pore pressure with moisture changes. Initial shrinkage occurs in all building materials that are cement/lime based such as concrete, mortar, masonry and plasters. Generally heavy aggregate concrete shows less shrinkage than light weight aggregate concrete [7].

Swelling pressure is the pressure, which prevents the specimens from swelling. i.e., It is the pressure required to return the specimens back to its original state after swelling (Void ratio, height). Swell is influenced by initial moisture content, initial dry density, surcharge pressure, time allowed for swell, size and stratum thickness and degree of saturation. As the sample is subjected to moisture, the degree of saturation increases as a result swelling potential increases but the swelling pressure is unchanged [5].

2.5. Causes of Defects

2.5.1. Human Action

Improper calculation methods and errors, insufficient technical information and level of detailing, improper design assessment, Use of bad quality materials, inadequately qualified and experienced personnel, inadequate execution control of construction works, bad interpretation of the project, no or inadequate maintenance procedures, changes in the utilization, excessive loading, fire, explosion, e.t.c. the quality of building materials and the absence or maintenance quality are less frequently considered as the cause[2].

2.5.2. Expansive Soil

Cracks caused by swelling soil are wide at the top and narrow at the bottom. The cause of foundation movement is moisture fluctuation of the foundation soil. Normally, the first sign of foundation movement for a structure founded on expansive soil is the cracking of the floor slab, door binding, window stacking and cracks appearing in the exterior and in the interior walls and even in the ceiling . It is important to differentiate the different types of cracks and their causes in order to know cracks caused by expansive soil heave. It is difficult or costs a lot to make an absolute crack free building [12].

2.5.3. Compaction

Compaction is the application of mechanical energy to a soil to rearrange the particles and reduce the void ratio. Compaction is the process of increasing the Bulk Density of a soil or aggregate by driving out air. For any soil, at a given compactive effort, the density obtained depends on the moisture content. An "Optimum Moisture Content" exists at which it will achieve a maximum density. Compaction is the method of mechanically increasing the density of soil. The densification of soil is achieved by reducing air void space. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933,therefore, the test is also known as the Proctor test[13].

In case of a building built on soil which is not very compact, sometimes settlement starts when water due to unusually heavy rains or unexpected floods gets into the foundation and causes settlement in the soil under load of the structure. Such a settlement generally not being uniform in different parts, results in cracking. Plinth protection around the building help to some extent in preventing seepage of rain and surface water into the foundation, thereby obviating the possibility of settlement cracks [14].

Poor soil compaction is a serious problem that can cause settlement when backfilling it required for the backfilling to be compacted at each layers usually at every 150mm. most contractors backfill the soil in one layer rather than several layers, therefore, they only compact the top layer. Since, the bottom soil is not well compacted or not even compacted, it will settle at a later stage and cause settlement in the building which can results in a continuous cracking of wall and foundation failure [4].

2.5.4. Thermal Movements

Thermal movement is one of the most potent causes of cracking in buildings. All materials more or less expand on heating and contract on cooling. The thermal movement in a component depends on a number of factors such as temperature variations, dimensions, coefficient of thermal expansion and some other physical properties of materials [7].

Tensile and compressive stresses develop within the building elements due to temperature changes. The magnitude of the stress depends on the coefficient of thermal expansion of the material. Cracks can occur if the building element is restrained and lacks sufficient joints to accommodate the movement. The cracks due to thermal movement is caused either due to external heat i.e. due to variation in ambient temperature, or due to internally generated heat i.e. due to heat of hydration in mass concrete during construction [2] .

2.5.5. Changes in Moisture Content

Most of the building materials (e.g. Concrete, mortar, burnt clay brick, timber, plywood etc.,) are porous in their structure in the form of inter-molecular space, and they expands on absorbing moisture from atmosphere and shrinks on drying. These movements are reversible i.e. cyclic in nature and are caused by increase or decrease in the inter-pore pressure with moisture change. Extent of movement depends upon molecular structure and porosity of a material.

Apart from reversible movement certain materials undergo some irreversible movement due to initial moisture changes after their manufacture or construction. The incidences of irreversible movement in materials are shrinkage of cement and lime based materials on initial drying i.e. initial shrinkage/plastic shrinkage and expansion of burnt clay bricks and other clay products on removal from kilns i.e. initial expansion [2].

2.5.6. Foundation Movement

Shear cracks in buildings occur when there is large differential -settlement of foundation either due to unequal bearing pressure under different parts of the structure or due to bearing pressure on soil being in excess of safe bearing strength of the soil or due to low factor of safety in the design of foundation. Sometimes, differential settlements in buildings occur when there are local variations in the nature of supporting soil ‘and such variations are not detected and taken care of in the foundation design at the time of construction. In order to avoid settlement cracks in buildings. it is essential that designs for their foundations are based on sound engineering principles and good practice[14].

The magnitude and intensity of structural damage is influenced by the intensity of contact pressure, the type of foundation and the relative stiffness of the super structure. In lightweight structures, the contract pressure is normally much smaller than the swelling pressure of the expansive soil. As a result, the whole building will be lifted differentially and creates stresses, which are not accounted on the design. This stress creates cracks. The first sign of foundation movement for structures founded on expansive soil is the cracking of the floor slab, door binding, window sticking and cracks appearing in the exterior and interior walls and even in the ceilings[5].

2.5.7. Movement Due To Chemical Reaction

Certain chemical reactions in building materials result in appreciable increase in volume of materials, due to which internal stresses are setup which may results in outward thrust and formation of cracks. The material involve in reaction also become weak in strength. The common instances of chemical reactions are :

- Sulphate attack
- Carbonation in cement based materials
- Corrosion of reinforcement in concrete
- Alkali-aggregate reaction.

2.5.7.1. Sulphate Attack

Soluble sulphates which are sometimes present in soil, ground water or clay bricks reacts with tri-calcium aluminate content of cement and hydraulic lime in the presence of moisture and form products which occupies much larger volume than the original constituents. This expensive reaction causes weakening of masonry, concrete and plaster and formation of cracks. For above reaction it is necessary that soluble sulphate, tri-calcium-aluminate and moisture, all the three are present. It takes about 2 or more years before the effect of this reaction becomes apparent. Movement and cracks due to this reaction in the structures appears after about 2 years or more. The severity of sulphate attack depends upon

- Amount of soluble sulphates present
- Permeability of concrete and mortar
- Content of tri-calcium-aluminate in the cement used for concrete and mortar
- Duration for which the building components remains damp.

The building components, which are, liable to sulphate attack are concrete and masonry in foundation and plinth, and masonry and plaster in super structure. The sulphate attack on these components will result in weakening of these components and in course of time may result in unequal settlement of foundation and cracks in super structure.

2.5.7.2. Carbonation

During hardening of concrete some calcium hydroxide is liberated in the process of hydration of cement. It provides protective alkaline medium inhabiting galvanic cell action thus preventing corrosion of steel. In course of time, free hydroxide in concrete reacts with atmospheric carbon-di-oxide forming calcium carbonate resulting in shrinkage cracks, since calcium carbonate occupies lesser volume than calcium hydroxide. This phenomenon known as carbonation, also reduces the alkalinity of concrete hence its effectiveness as a protective medium for reinforcement. In good dense concrete carbonation is confine mainly to surface layer and depth of carbonation normally not exceeds 20 mm in 50 years. In porous concrete it may reach 100 mm in 50 years. The effect of carbonation is more severe in industrial locality having higher percentage of carbon-di-oxide in the atmosphere.

2.5.7.3. Corrosion of Reinforcement

A properly designed and constructed concrete is initially water-tight and the reinforcement steel within it is well protected by a physical barrier of concrete cover which has low permeability and high density. Concrete also gives steel within it a chemical protection. Steel will not corrode as long as concrete around it is impervious and does not allow moisture or chlorides to penetrate within the cover area. Steel corrosion will also not occur as long as concrete surrounding it is alkaline in nature having a high pH value.

Concrete normally provides excellent protection to reinforcing steel. Notwithstanding this, there are large number of cases in which corrosion of reinforcement has caused damage to concrete structures within a few years from the time of construction resulting in loss of mass, stiffness and bond in concrete and therefore concrete repair becomes inevitable as considerable loss of strength takes place [7].

2.5.7.4. Alkali Aggregate Reaction

In ordinary Portland cement sodium oxide and potassium oxide are present to some extent. These alkalis chemically react, with certain siliceous mineral constituents of aggregate and causes expansion, cracking and disintegration of concrete. In reinforced concrete member it also causes corrosion of reinforcement. Cracking due to this reaction is usually of a map pattern, and the reaction being very slow, it takes nos. of years for cracks to develop[3].

2.6. Method of Measurement

2.6.1. Epoxy Injection

Cracks as narrow as 0.002 in. (0.05 mm) can be bonded by the injection of epoxy. The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure. Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams, and other types of concrete structures (ACI 503R). However, unless the cause of the cracking has been corrected, it will probably recur near the original crack [7].

2.6.2. Routing and Sealing

Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant. This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole) [7].

2.6.3. Stitching

Stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack. Stitching may be used when tensile strength must be reestablished across major cracks. The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non-shrink grout or an epoxy resin-based bonding system [7].

2.6.4. Drilling and Plugging

Drilling and plugging a crack consists of drilling down the length of the crack and grouting it to form a key. This technique is only applicable when cracks run in reasonable straight lines and are accessible at one end. This method is most often used to repair vertical cracks in retaining walls. A hole [typically 2 to 3 in. (50 to 75 mm) in diameter] should be drilled, centered on and following the crack [7].

2.6.5. Gravity Filling

Low viscosity monomers and resins can be used to seal cracks with surface widths of 0.001 to 0.08 in. (0.03 to 2 mm) by gravity filling. High-molecular- weight methacrylate, urethanes, and some low viscosity epoxies have been used successfully. The lower the viscosity, the finer the cracks that can be filled. The typical procedure is to clean the surface by air blasting and/or water blasting. Wet surfaces should be permitted to dry several days to obtain the best crack filling [7].

2.6.6. Overlay and Surface Treatments

Fine surface cracks in structural slabs and pavements may be repaired using either a bonded overlay or surface treatment if there will not be further significant movement across the cracks. Unbounded overlays may be used to cover, but not necessarily repair a slab. Overlays and surface treatments can be appropriate for cracks caused by one-time occurrences and which do not completely penetrate the slab [7].

CHAPTER THREE

3. Sampling Methodology and Previous Test Result Data

3.1. General

As in the observation and data collection to the area, the area soil is found to be an expansive soil type. So due to the expansiveness property of the soil most of the buildings, roads, walk ways and pavements are damaged seriously. In this project focused on the causes of damage of buildings on the ecpansive soil area. most of the residential buildings are newly constructed under 20/80 and 10/90 condominium projects and lightweight buildings, which are susceptible to damage caused by expansive soil . These are mainly constructed from Hollow concrete block, CIS and 'checa' wall. By taking samples from the population inference can be made about the buildings those constructed in expansive soil areas, A normal distribution is applied for the determination of sample size.

3.2. Geotechnical Characteristics of the Study Area

Expansive Soils are known to occur in many part of the world. Such as: Argentina, Australia, Burma, Canada, Cuba, Ethiopia, Ghana, India, Iran, Israel, Mexico, Morocco, Poland, South Africa, Spain, Turkey, U.S.A, U.S.S.R and Venezuela have been identified. In Ethiopia,

particularly Addis Ababa where recent constructions are carried out the eastern and southern part of a city are extensively covered with expansive soil [5] and also by Abdrishkur [2015] research paper the koye feche soil test result is highly expandable soil type. Samples were taken from different locations of the study area to a depth of 3m. The top 0m to 1.5m depth is black in color and then the soil changes its color to grey. The laboratory test result showed both the black and the grey have similar properties.

3.3. Method of Sampling and Sample Size Determination

It is difficult to observe all the individual of the buildings because of the time and cost limitation. Based on this fact a random sampling method has been used to the study. The formula for the maximum sample size is obtained by solving the maximum error of the estimate formula for the population proportion for n. But since the sample hasn't been taken, there is no value for the sample proportion. p and q can be taken from a previous study, if it is available. If there is no previous study or estimate available, then use of 0.5 for p and q, as these are the values which will give the largest sample size, and it is better to have too large of a sample size and come under the maximum error of the estimate than to have too small of a sample size and exceed the maximum error of the estimate [9].

$$\mathbf{n = (\ z^2/d^2)*\ p*q}$$

Where

n = sample size to be studied

d= relative desired precision

P= sample proportion which are damaged

q= sample proportion which are not damaged

Z = Standard normal value

Assumptions

z = 95% confidence interval is used for most studies. This means that we can be 95% sure that the true population value for our damage assessment is within the limits of the interval calculated. At 95% confidence the value of z=1.96.

p = From previous studies in our county. by Afework Sisay (2004) [5] used p = 0.5(50%) which gives the maximum sample size. From his research he found out that 72% of the buildings are damaged due to expansive soils problems in Addis Ababa.

By Tibebu Solomon (2015)[10] used p = 0.72*72% from the previous result of Afewerk Sisay he has found 87% of the buildings are damaged because of expansive soil problem in Bahrdar.

There is no standard precision to use when planning a survey. Desired precision depends on the objective of the survey, estimated prevalence or rate, and resource available. Other things kept equal the higher your desired precision, the larger is the sample size. For this case study

+/- 10% precision value is used. Since the area is highly expansive soil type and the damaged buildings assumption to be taken from previous study by Afewerk Sisay (2004) the maximum sample size of p and q 0.5*50% he has found 72% of buildings were damaged. And by Tibebu Solomon 87% of the buildings were damaged. The Koye Feche soil test result by Abdrishikur Kemal (2015), shows a higher expansiveness property than by Tibebu Solomon in Bahrdar. So by relating the soil test result in Bahrdar by Tibebu Solomon and the test result in Koye Feche by Abdrishikur Kemal, prevalence value of 87% is used to the study. The sample size for 95% confidence interval for a maximum of 10% sampling error to represent the population is then calculated as 44.

3.4. Summary on Laboratory Test Results of the Area

Koye feche is found at southern part of Addis Ababa with a latitude of 8º54’47’’ North and a longitude of 38º47’21’’ East and has 2125m above sea level. At Koye-feche Abdrishkur Kemal [2015] studied on the corrrlation between index properties and swelling pressure of expansive soils found around koye area. From his laboratory test result of the soil investigation the summary of the test results are shown in appendices and The test pit samples were taken as shown fig. 3.2.

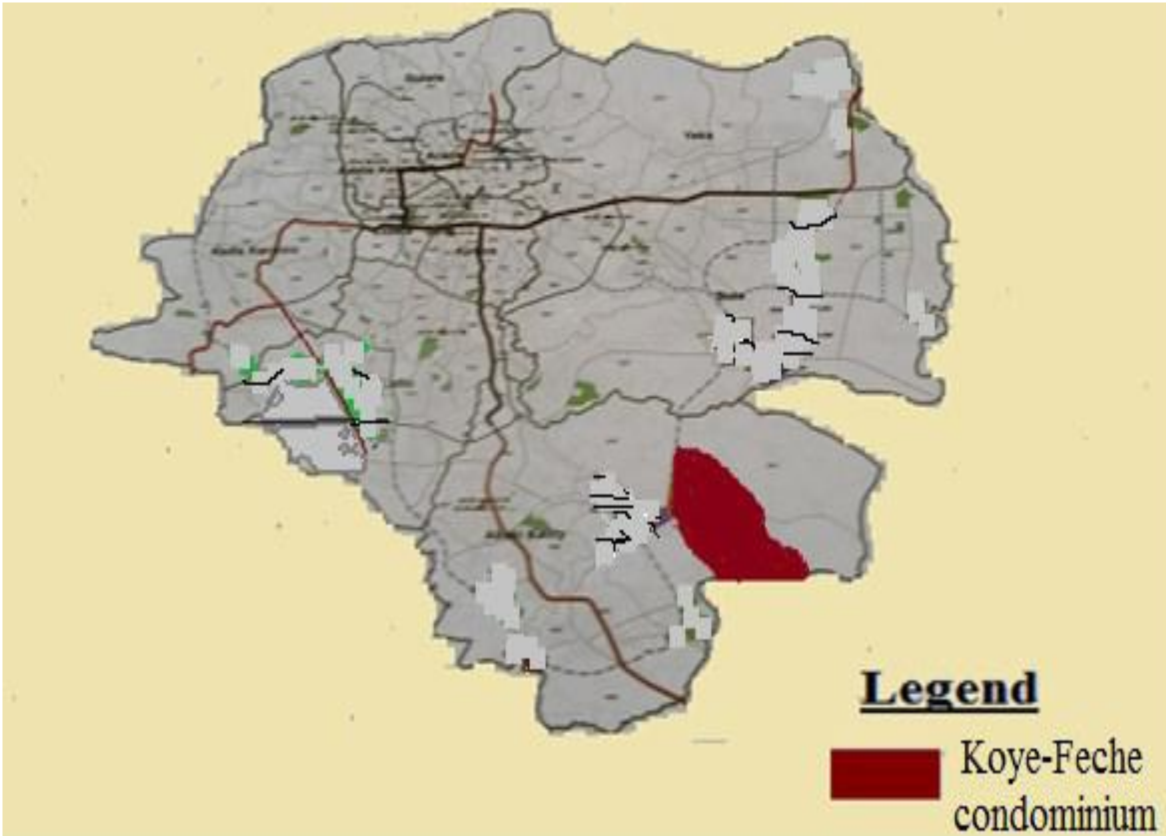

Figure 3.1: Location of Koye-Feche condominium in Addis Ababa city map

Source: Based on Maps from Addis Ababa city administration integrated land information center, Bureau of Land Development and Management, 2014

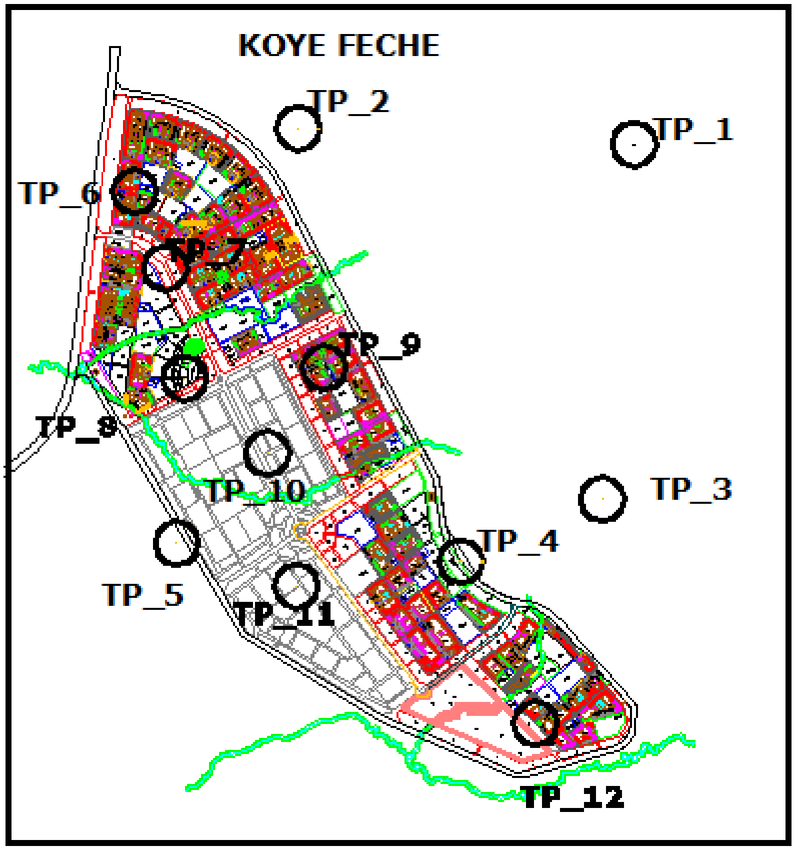

Figure 3.2. Location of test pits

According to Seed, Woodward and Lundgreen , Plasticity Index is a parameter which can be used as a preliminary indicator of the swelling characteristics of a soil. Based on this classification all samples of the study area have plasticity index of 55% and above it categorized under very high swell potential [11].

Seed, Woodward and Lundgreen suggested three classes of clays according to their plasticity index.

Swell Potential	Plasticity Index
Low	0-10
Medium	10-35
High	20-55
Very High	55 and above

CHAPTER FOUR

4. Data Observation and Damage Analysis

The data observations are carried out with respect to many parameters such as Foundation type, wall type, building type and drainage condition. As in methods of random sampling the total visited buildings are forty four as in table 4.1. From which eleven from project sixteen, eighteen from project seventeen, eleven from project eighteen and four from adisu sefer around wereda nine.

Table 4.1. No of sample building over expansive soil area at koye feche

No	Location	No of Building	Remark
1	Project 16	11	6 G+7, 4 G+4 and 1 CIS wall envelop with masonry
2	Project 17	18	7 G+7, 5 G+4, 1 hut, 2 agroston house and 1 mud house with CIS roof cover and 2 water reservoir constructed in ϕ20 HCB wall
3	Project 18	11	7 G+7 and 4G+4
4	Adisu sefer	4	2 mud house, 2 mud house plastered with mortar and leveled with masonry
5	total	44	

In table 4.2. From the total of 44 buildings 32 of them are damaged in different types of foundation at the different parts of the building. From the data observation hard core and concrete foundation constructed for water reservoir is totally damaged due to fluctuation of moisture content to the expansive soil. 80% of the masonry foundation is damaged, 75% of wooden post foundation are damaged, 68% and 71% of the mat foundation and isolated footing foundations are exposed to cracks on infill masonry respectively and the settlement of fill material.

Table 4.2. Damage of sample buildings related to foundation type

Type of foundation	No of buildings	No of damaged buildings
Mat foundation	19	13
Isolated footing	14	10
Masonry foundation	5	4
Wooden post foundation	4	3
Hardcore and concrete foundation	2	2
total	44	32

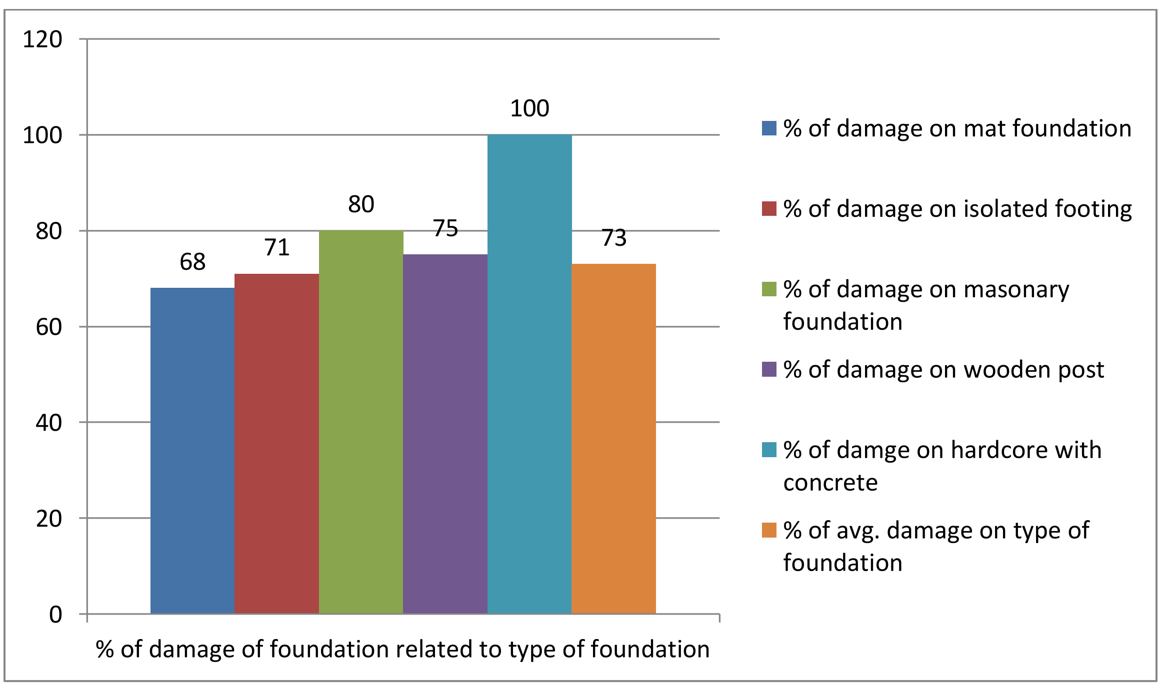

Figure 4.1. % of damaged building related to type of foundation.

I have visited the types of wall under sub structure and a wall above NGL which is directly affected by foundation movement or soil movement. From the observed data HCB work for water reservoir below NGL is completely damaged, 73% of infill masonry is damaged, 75%

of wooden post, 50% of wooden post leveled with masonry and 50% of agrostone walls are damaged due to swelling and shrinkage characteristics of expansive soil. A vertical string measurement has taken on one mud house at the bottom and the top of the house near to the roof cover. The measurement value at the bottom is 170mm and at the top is 510mm at the front side. The house loose it's verticality about 340mm inwards. This is shown below figure 4.3.c. and 4.3.d.

Table 4.3. Damage of sample building respect to wall type .

Wall type	No of visited buildings	No of damaged buildings
HCB below NGL for water reservoir	2	2
Masonry under grade beam	33	23
brick	0	0
Wooden post	4	3
Wooden post envelope with masonry	2	1
Agrostone with masonry foundation	2	1
CIS	1	0
total	44	30

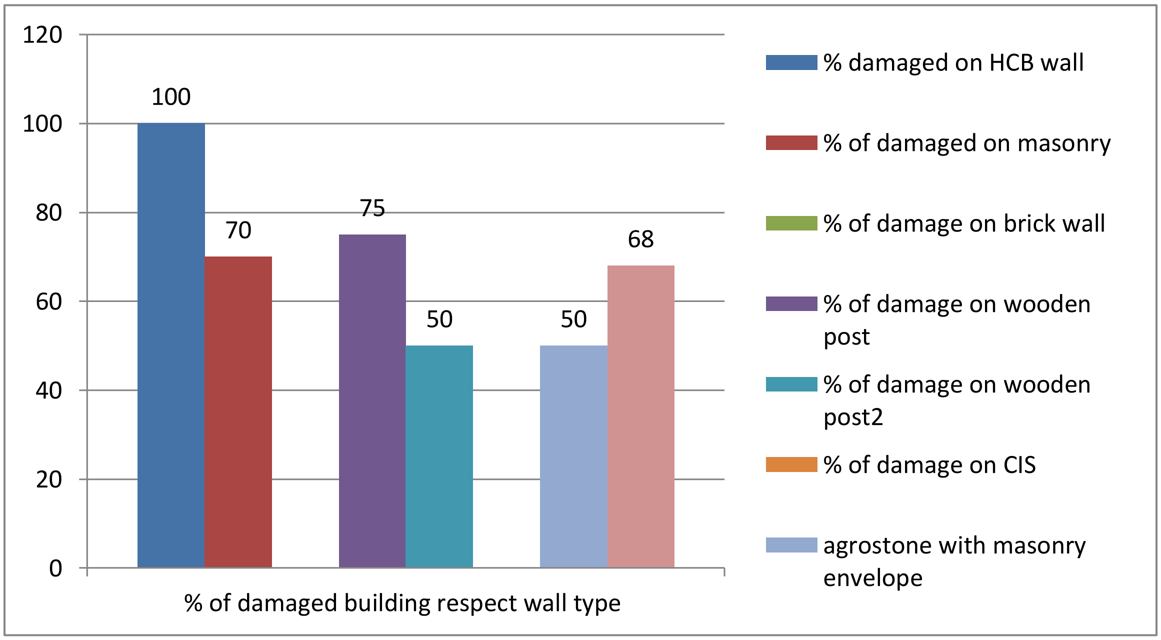

Figure 4.2. Percentage of damaged buildings respect to wall type.

Figure 4.3.a. sample picture on damage of masonry under grade beam

Figure 4.3.b.a vertical string measrement of a wooden post house with CIS roof cover sloping to inwards

Figure 4.3.c. vertical string measrement at the Bottom is 170mm

Figure 4.3.d.vertical sting measurement at the top is 510mm

Figure 4.3.e. sample pictures damaged of Mud plaster

Figure 4.3.f. crack on agroston wall throughout masonry foundation

From the observed sample 33 buildings are taken from newly under construction condominium projects. The damage on this buildings are found on the masonry and the back fill under grade beam. So the masonry crack is visited indifferently to the column axis and the cantilever part for each type of the building. Damage to the infill masonry on the major axis is 40% on the G+7 buildings and 54% on the G+4buildings. The G+7 masonry on the column axis is started on the mat beam and it shows a lesser percent of crack is observed.

Table 4.4. Damage of masonry respect to the major axis of the building

Part of infill masonry	No of visited buildings	No of damaged buildings on the major axis
On the G+7 buildings	20	8
On the G+4 buildings	13	7
total	33	15

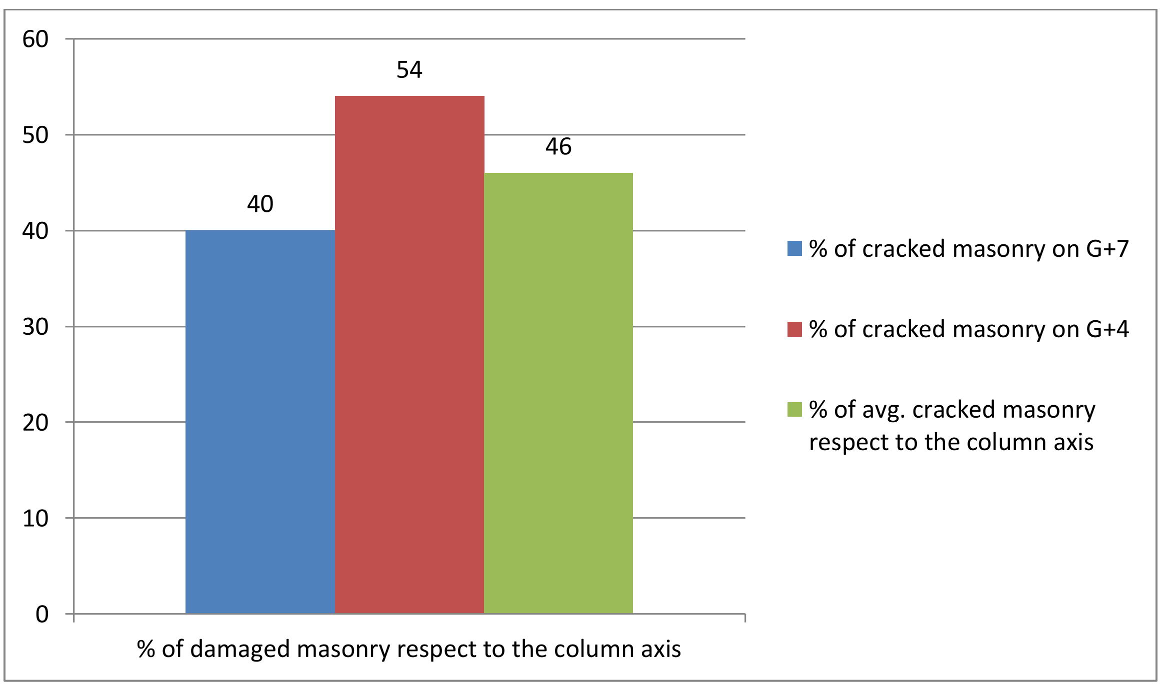

Figure 4.4. Percentage of damaged infill masonry respect to the column axis.

Figure 4.5. sample pictures to masonry crack on the column axis.

Damage of masonry on the cantilever 65% on the G+7 buildings and 62% on the G+4 buildings from the total. But respect to the damaged building number 100% on the G+7 and 80% on the G+4 shows crack on cantilever.

Table 4.5. Damage of masonry respect to the cantilever

Part of infill masonry	**No of visited buildings**	**No of damaged buildings on the cantilever**
On the G+7 buildings	20	13
On the G+4 buildings	13	8
total	33	20

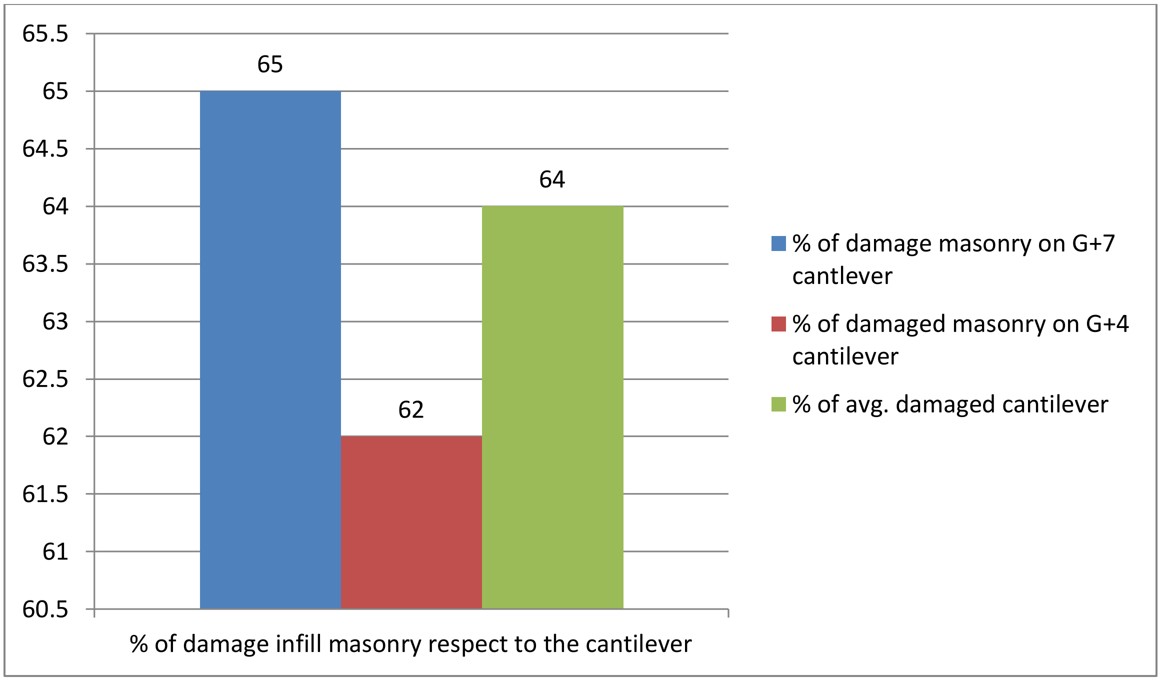

Figure 4.6. Percentage of damage masonry respect to the cantilever.

Figure 4.7. Sample picture of damaged masonry on the cantilever part of the building

Figure 4.8.a mat foundation to G+ 7 Building Under constructions

Figure 4.8.b. isolated foundation of G+4 building under construction

From the table 4.6. shown below 80% of cement screed floor is cracked due to expansive soil effect and 70% of compacted soil under grade beam is settled due to less compaction. The floor found on mud houses are not considered due to their flexibility of the floor.

Table 4.6. Damage on the floor concrete and compacted fill material settlement

Type of floor observed	No of visited buildings	No of damaged buildings
Cement screed and hard core	5	4
Compacted soil under grade beam	33	23
Total respect to floor	38	27
Not observed floor	6	0
Respect to observed building	44	27

Figure 4.9. Percentage of crack on ground floor and settlement of backfill.

Figure 4.10. Sample picture of Floor crack at office of site inspector about 40mm wide.

Figure 4.11. Settlement of fill material under grade beam due to less compaction down 250mm.

Table 4.7. Number of damage observed on building type

Building type	No of observed building	No of damage at least one part of the building or more	% of damage respect to building type
G+7	20	13	65%
G+4	13	10	77%
G+0 CIS, mud house or plastered with mortar, agrostone	9	7	78%
Water reservoir tanker	2	2	100%
total	44	32	73%

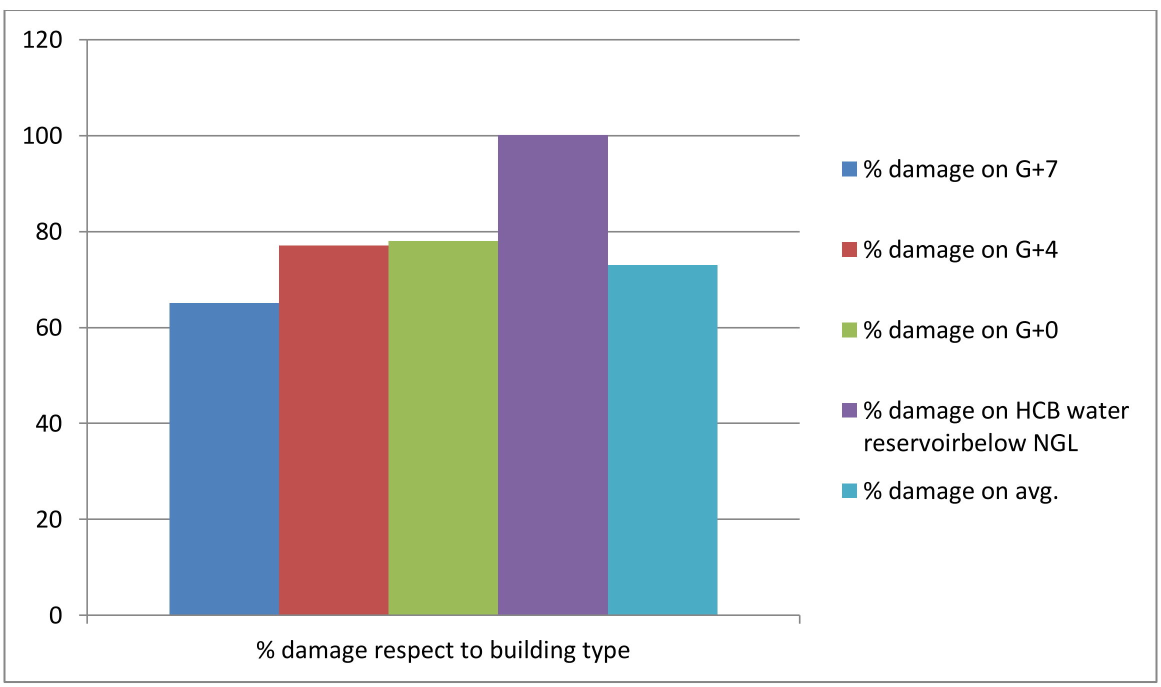

Figure 4.12. Percentage of damage respect to building type.

CHAPTER FIVE

5. Discussion and Results

This study is focused on a total of forty four buildings from the koye feche building construction projects. eleven buildings from project 16, eighteen from project 17, eleven from project 18 and four from adisu sefer, which is found in between project 17 and Akaki kality project. I have taken thirteen buildings from G+4, twenty buildings from G+7 and one CIS of cafeteria, one hut, two agroston house office of inspector, five mud house with CIS roof cover and two water reservoir constructed in ϕ20 HCB.

From the total of 44 visited number of buildings 32 of them, which is 73% of the building, are exposed to minor crack to sever crack because of the expansive soil effect. seepage of water to the foundation and improper compaction of fill material affects the maximum dry density of the soil. The excavated area around the building is not filled with select material or other material which is adversely affect the foundation and cause for water accumulation. the backfill payment around the building is not payable to the contractor to minimize the cost of the project. Due to this problem water enter to the building and shows an out ward wall movement on some buildings but at this time after three years of excavation period the Engineer order to fill the select material around the building.

Figure 5.1. Out ward movement of masonry due to unbalanced force

Even if the G+7 buildings are mat foundation type except that one building, which is isolated footing due to the presence of a hard basaltic rock, there is also a cantilever part. it is projected from the grade beam and not excavated properly to the depth of the foundation. It is simply excavated a trench excavation not fill with select material under masonry due to this problem from 20 observed buildings 13 of them are affected, which is 65% of it is damaged. And from 13 observed building 8 of them are damaged on G+4 buildings, which is 62% of the total. But related to the damage building 100% of the G+7 building cantilever are damage and 80% of the G+4 building cantilever are damaged.

Figure 5.2. Masonry crack on the cantilever.

The compaction of the fill material is not done according to the agreement in layer of 200mm. It is simply fill the select material using loader and compacted the soil at the top of the fill under grade beam by eight tone roller for a depth of more than 2500mm. Due to compaction problem of the soil shown in sample picture up to 250mm settlement of the fill material is observed.

Figure 5.3. Filling select material under grade beam with loader

Figure 5.4. Fill material settlement under grade beam up to 250mm.

As shown in figure below 5.5. and 5.6. Seepage and accumulation of water under the building will fluctuate the moisture content of the expansive soil and also wash out the fill material. Because of this washing out of the fill material it loose it’s dry density and the expansive soil is exposed to swelling and shrinking characteristics. The entered water to the building expands the soil under back fill since the area soil has a high swelling potential. These swelling and shrinking characteristics of soil produce cracks to the buildings.

Figure 5.5. Accumulation of water around the building

Figure 5.6. Seepage of water under the foundation.

Maintaining cracks with appropriate method can increase the serviceability of the building otherwise it is maintained periodically. Then it becomes coasty and it has a psychological impact to the dwellers. Sample pictures shown in fig. 5.7. Maintained before with thick mortar and cracked again so it is difficult to maintain periodically and it reduce the serviceability time of the building if not taken the right measurement to the damage.

Figure 5.7. Improper maintenance of masonry cracks with a thick mortar.

CHAPTER SIX

6. Conclusion and Recommendation

6.1. Conclusion

- Expansive soils are the soils which expand when the moisture content of the soil is increased. The clay mineral montmorillonite is mainly responsible for expansive characteristics of the soil and exposed to Sever movements of the soil mass. Structures built on such soils may experience cracking and damage due to differential heave. The damages can be prevented to a large extent if the characteristics of the expansive soil are properly assessed and suitable measures are taken in the design, construction and maintenance of structures built on expansive soils.
- Proper prevention measure shall be used in accordance with design of foundation, replacement and modification of expansive soil. In the case of design there is no major problem except that design modification. And also all the newly constructed condominium projects on the area replace all the expansive soil with non-expansive granular select material. But the modification of the soil on the project is poor, which is not used proper compaction method. The compaction is done filling the whole select material by using loader and compact on eight tone roller once on the top under grade beam for a depth of greater than 2.5m and also there is no any addition of water to the soil during compaction, so the optimum moisture content of the soil may not be achieved.
- Less awareness to the characteristics of the expansive soil on the construction parties or there is a negligence during construction period on the contractor side and also on the consultant supervisors affects the serviceability limit of the building and durability of the building.
- The failure on masonry in the cantilever has a greater percent than that on the major axis. It shows that the excavation depth, the backfill or compaction of the soil is not done accordingly.
- Out of randomly selected 44 buildings 32 of them, which is about 73% of the total buildings are damaged at least one part of the building due to expansive soil effect and using a lesser work methodology on the site.

- ❖ Walls on HCB under NGL and floor concretes on expansive soil which has a lesser modification is completely damaged due to the swelling and shrinkage characteristics of the expansive soil.

6.2. Recommendation

To minimize cracks or damages in buildings found on expansive soil area the following recommendations will be given:

- ❖ It is recommended to apply all existing available theories and practices for the design and constructions of buildings located in expansive soil areas.
- ❖ Based on the field investigation, soil tests result and damage analysis of expansive soil,
  design guide or national building code for expansive Soil and need to be prepared.
- ❖ Existing buildings: covered area around the building should be increased by providing concrete/masonry aprons or impervious membrane around the building. This action will considerably reduce the seasonal moisture fluctuation which in turn reduce the ground movement.
- ❖ A land use policy on expansive soil areas of Addis Ababa can be prepared by Professionals and city administration.
- ❖ The result obtained may be used as a basis for further research in the area of expansive soil.

- ❖ it is impossible to guarantee against cracking yet attempts can be made to minimize development of crack. And also, not all type of crack requires same level of attention. The potential causes of crack can be controlled if proper consideration is given to construction material and technique to be used. In case of existing cracks, after detail study and analysis of crack parameters, most appropriate method of correction should be adopted for effective and efficient repair of crack.

- ❖ To avoid the issue of faulty construction and its effects on building maintenance all the stakeholders must work as a team in order to achieve the project results.

- Contractors must endeavor to comply with the specifications provided by the designers to avoid defects.

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APPENDIXES

APPENDIX A

Summary of the laboratory soil test results of koye feche

Location	TP	Depth (m)	Color	%LL	%PL	% PI	LI	ρd	ω	Free swell%	SP% (kpa)
Tulu mute	TP 1	3	Dark grey	104.5	41.8	62.6	0.04	1.22	44.55	152.5	190
Ula	TP 2	3	grey	100.9	38	62.9	0.11	1.12	44.93	132.5	150
Gara duba	TP 3	3	Redish grey	100.9	37.8	63.1	0.11	1.18	45.02	165.0	140
Koye abo	TP 4	3	Yellowish grey	90.4	34.6	56.2	0.21	1.11	46.14	95.0	80
Wereda 9	TP 5	3	Whitish grey	100.1	37.1	63.1	0.03	1.29	38.9	217.5	260
Project 16 pit 1	TP 6	1.5	black	97.3	37	60.3	0.14	1.20	45.17	175.0	150
		3	Brownish grey	94.7	35.4	59.4	0.12	1.26	42.63	195.0	230
Project 16 pit 2	TP 7	1.5	black	108	40.8	67.2	0.02	1.29	42.17	192.5	250
		3	Brownish grey	92.4	35	57.4	0.15	1.24	43.65	147.5	180
Kersa	TP 8	1.5	black	100.1	37.2	62.9	0.02	1.28	38.32	202.5	250
		3	Brownish grey	98.4	38.8	59.6	0.01	1.26	39.34	187.5	240
Project 17 pit 1	TP9	1.5	black	99.8	38.6	61.2	0.09	1.19	44.31	122.5	140

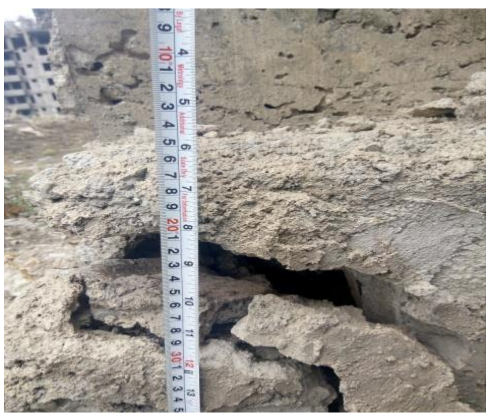
		3	Whitish grey	105.3	39.4	65.9	0.09	1.18	45.33	145.0	120
Project 17 pit 2	TP10	1.5	black	111.8	42.7	69.1	0.01	1.23	43.58	215.0	200
		3	Whitish grey	108.1	41.7	66.4	0.02	1.26	43.16	200.0	250
Project 18 pit 1	TP11	1.5	black	110.9	42.5	68.4	-0.08	1.32	37.17	217.5	400
		3	Brownish grey	105.2	38.7	66.5	-0.01	1.30	37.83	210.0	350
Project 18 pit 2	TP12	1.5	black	109.8	41.8	68	0.01	1.27	42.71	180.0	250
		3	Dark grey	113.3	43.1	70.3	0.03	1.21	45.32	135.0	190

APPENDIX B









Observed Sample pictures of damaged masonry on site

Sample pictures on settlement of fill material under grade beam and cracks on ground floor due to expansive soil effect and less compaction method

Sample pictures on damage of walls on agrostone, mud house and reservoir tanker.

Sample pictures on foundation under construction on the project

Accumulation and seepage of water under foundation on the project.